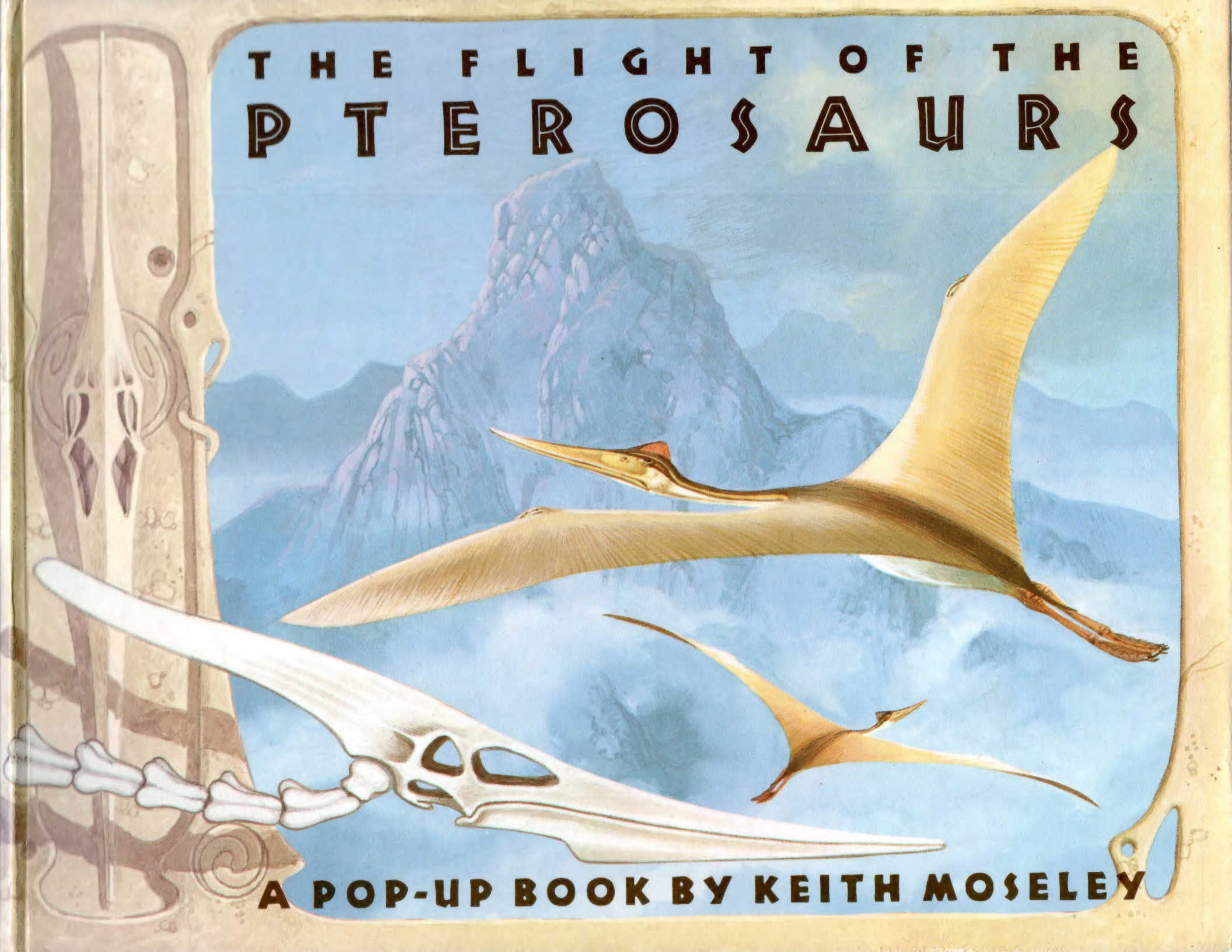
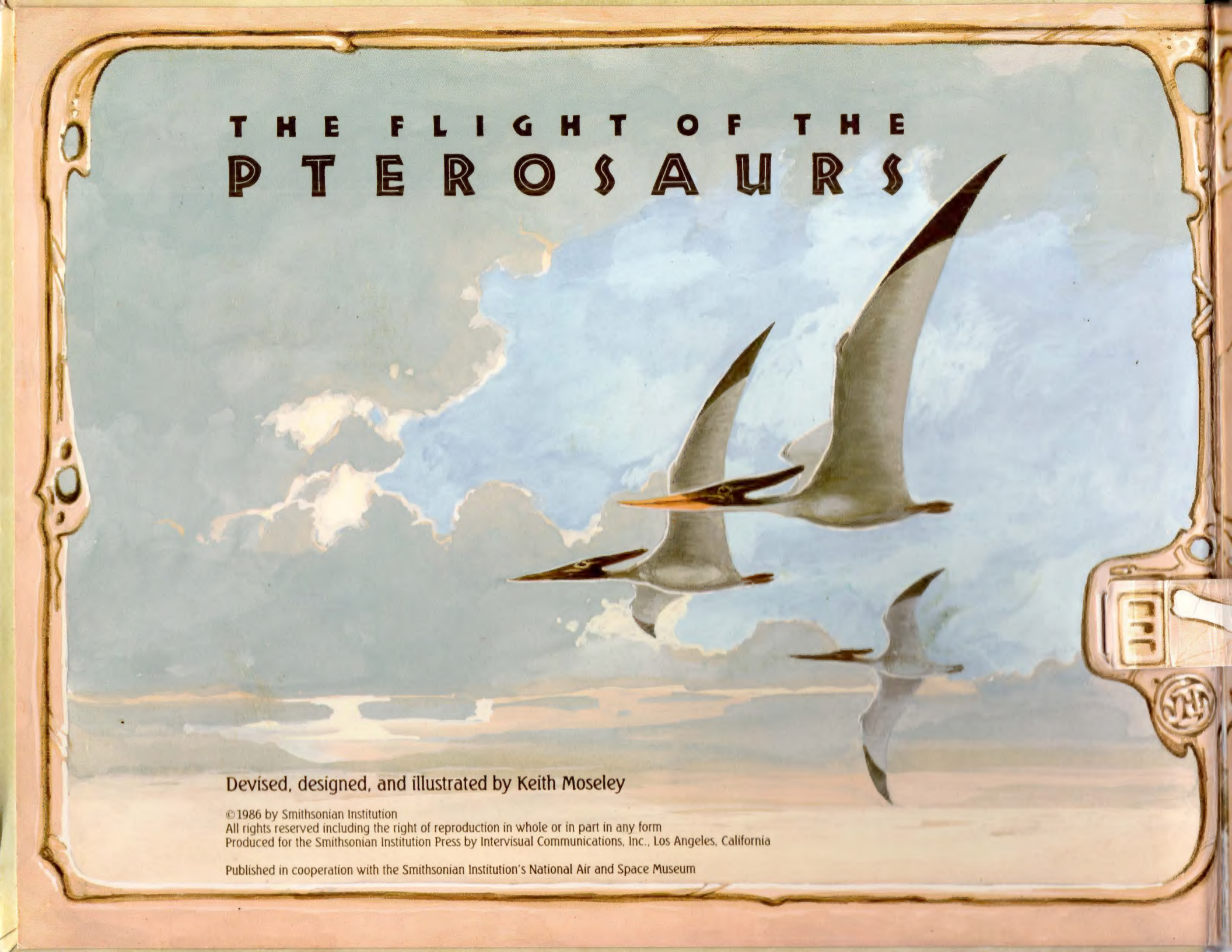

THE FLIGHT OF THE
PTEROSAURS
A POP-UP BOOK BY KEITH MOSELEY

THE FLIGHT OF THE PTEROSAURS



Devised, designed, and illustrated by Keith Moseley

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The Pterosaurs appeared quite suddenly as completely successful creatures, fully developed and able to sustain their own way of life among their competitors of the Triassic period more than 215 million years ago.

They were not dragons of the sky with leathery wings and scrawny necks, with cruel claws and vicious snapping jaws, but rather a line of elegant creatures that varied in size from that of a sparrow to a small commuter aircraft.

Picture them as covered in a sleek coat of fur like a mink or an otter, with long silky hair overlying a smooth streamlining underfur, like the feathers and down of a bird.

Visualize their color, bluegray or white as the familiar sea birds, or the speckled browns, pale buffs and darker shades of the hawks and eagles that live inland.

See in your mind's eye a living, breathing life that no one who ever lived has seen.

Witness the grace and beauty of the giants that sailed those unknown skies and picture the small ones that made their lives and raised their young on the banks of never-charted streams.

Hear the call of the giants, echoing across the voids between the thunderclouds that blossomed in that ancient air, and listen to the piping call of a small one returning to its nestlings.

Dispel forever the myth that these so fragile and delicately wrought beings were hideous and brutal monsters.

Strange they were and unfamiliar to eyes that have known only the forms and colors of robins and eagles, of gulls and sparrows, but they were of another time.

They were of a time before the great extinction of the dinosaurs, when the Brontosaurus thundered its way across the ancient world, and they knew firsthand the awesome ferocity of *Tyrannosaurus rex*.

Shown here full size is the skull of *Eudimorphodon ranzii*, one of the earliest known pterosaurs, a rhamphorhyncoid dating from the Late Triassic period, about 180 million years ago. It was discovered at Cene, near Bergamo, Italy.

The skull of *Eudimorphodon* measures 3.5 inches and its wing span, 32 inches.

Rhamphorhynchus

Down in the watery nook
Where bearded mists divide,
The grey old gods whom chaos knew
The sires of nature hide.

Ralph Waldo Emerson

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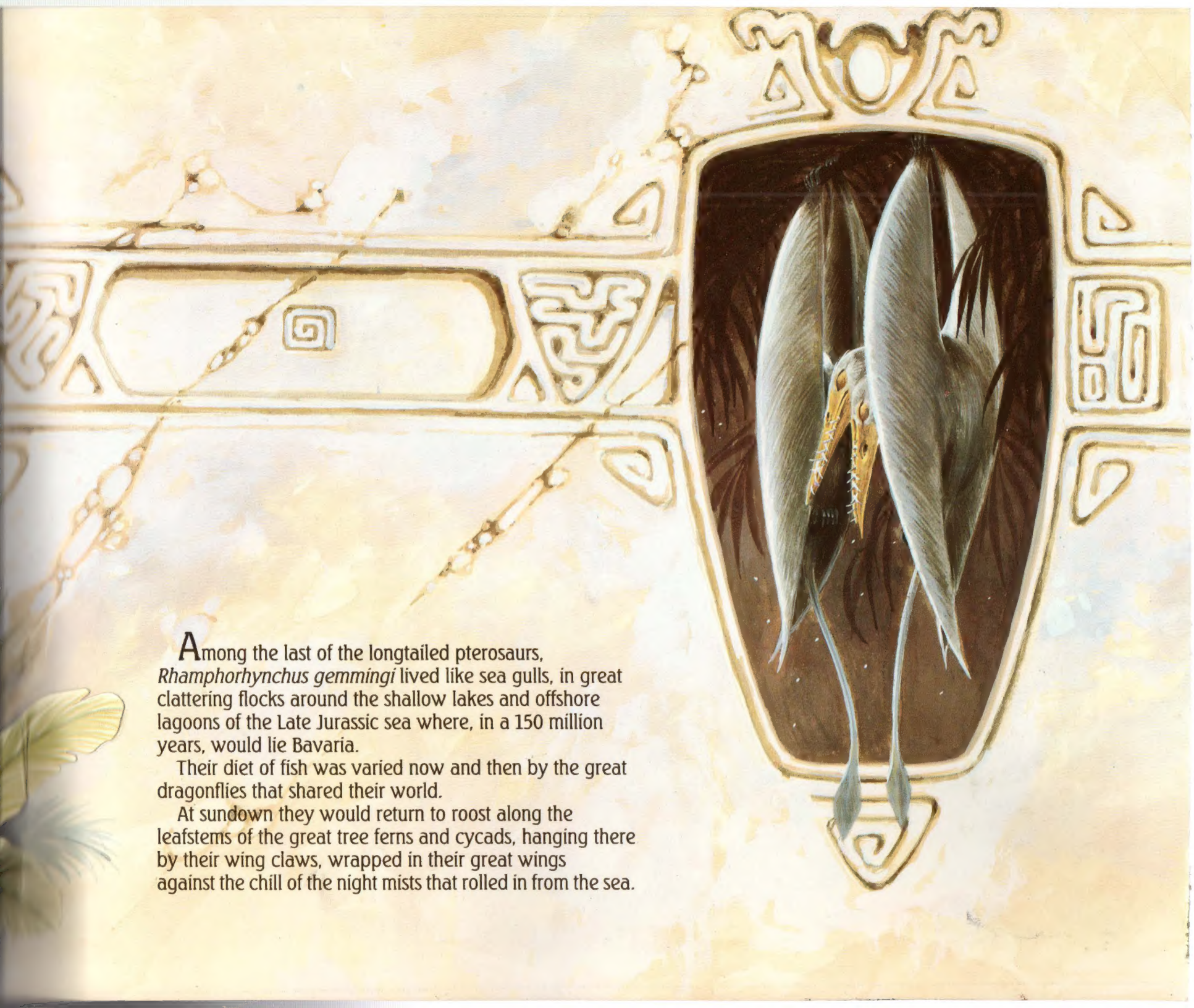

Among the last of the longtailed pterosaurs, *Rhamphorhynchus gemmingi* lived like sea gulls, in great clattering flocks around the shallow lakes and offshore lagoons of the Late Jurassic sea where, in a 150 million years, would lie Bavaria.

Their diet of fish was varied now and then by the great dragonflies that shared their world.

At sundown they would return to roost along the leafstems of the great tree ferns and cycads, hanging there by their wing claws, wrapped in their great wings against the chill of the night mists that rolled in from the sea.

This kind of *Rhamphorhynchus*, called *gemmingi*, was found in limestone in the West German province of Bavaria.

A long upper arm and forearm attached to a very long flight finger, a much modified little finger, typifies the structure of all pterosaurs. Bones that were hollow, in many cases with a wall less than one twenty-fifth of an inch thick, not only made tubes of great strength for their weight but formed air passages similar to those in the skeletons of birds.

Rhamphorhynchus had a head as long as its body (about 5 inches), with large eye sockets and the round brain case of creatures with highly developed eyesight and a mental capacity quite similar to that of a bird of today and much greater than its earthbound contemporaries.

Its long triangular jaws were armed with a variety of oddly spaced spearing teeth set in simple sockets.

Its long bony tail ended in a flap of skin set vertically, just like the fin and rudder of a plane.

Its wing span was 5.5 feet.

The delicat
Scaphognathu
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pterosaurs co
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One of the earliest pterosaurs, *Dimorphodon* flourished in the Jurassic period, some 150 million years ago.

Its jaws contained 2 forms of teeth. The front were long and pointed and the equally sharp back teeth were shorter. In fact, its scientific name means "two kinds of teeth."

Its 8-inch-long head had yet to assume the beaklike jaws of its later cousins. Its skull was almost a puffin's skull but its weight was small, lightened by large cavities separated only by thin struts of bone.

Dimorphodon was discovered at Lyme Regis in 1829 and was the first pterosaur known from England.

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ngland.

The delicate toes of *Scaphognathus* touch down lightly on a midstream boulder. The low wing loading and stall speed of the pterosaurs combined to allow gentle landings on digits that appear excessively fragile.

The wings of *Scaphognathus* spanned 5 feet and its skull, with jaws containing 30 widely spaced teeth, was 5 inches long.

Toothy and lightweight, a sea gull, some 30 inches. its lower jaw of 6 or 7 inche Four similar teeth, mounted with the 6 lowers. Except for muzzle, this creature, discov body to *Dimorphodon* from

Toothy and lightweight, *Dorygnathus* matched the wingspan of a sea gull, some 30 inches. Six long spearing teeth protruded from its lower jaw of 6 or 7 inches, which itself ended in a bony spike. Four similar teeth, mounted in the long, triangular skull, interlocked with the 6 lowers. Except for the dental prominence and slender muzzle, this creature, discovered at a German site, is similar in the body to *Dimorphodon* from England, opposite.

Pterodactylus elegans

These old flying animals sleep through geologic ages... and in cleaving the rocks to display their bones we have opened a new page of the book of life.

H. G. Seeley

ctylus elegans

Truly, these were the sparrows of the Mesozoic age, family parties of busy bustling little creatures dotting the margins of the tide pools. They picked stranded small fry from the fine wet sand or hunted among the crinoids, the sea lilies, for newly hatched insect larvae.

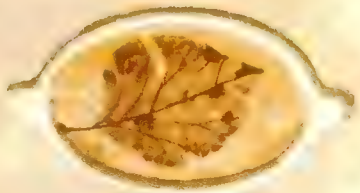
This was *Pterodactylus elegans*, the smallest and most finely built of all the pterosaurs.

Their lives came to an end beside the same quiet waters that had nurtured them, and the fine white sand that claimed their tiny fragile forms preserved them as fossils through the eons to come.

The fossils of *Pterodactylus elegans* were discovered in the finely grained limestone at Solnhofen in West Germany, limestone laid down in the Late Jurassic period.

Its wing span was only 10 inches and its skull a mere 1.25 inches long.

That same bed of limestone also preserved the first of a new line of creatures, a competitor to little *Pterodactylus elegans*. This was *Archaeopteryx*, a close relative of a small dinosaur and the forerunner of all the birds we know today.



Reminiscent of the straining devices found in some ducks and flamingoes were the 300 bristlelike teeth set in the long slender beak of *Ctenochasma*.

It was a dibbler, searching the shallows for its food, then holding the wriggling morsels loosely trapped within its bristle-hemmed beak while with quick sideways movements of its head it washed away the mud.

Discovered at Solnhofen in Germany in 1837, *Pterodactylus kochi* had long slim jaws with small interlocking teeth perfectly suited for catching the large fat insects living on the margins and in the meandering streams which formed their world.

The slender wings of *Pterodactylus kochi* spanned about 18 inches supporting a blackbird-sized body with a slim skull 3 inches long.

Pictured here lifesize, *Pterodaustro* was a filter feeder. Its lower jaw was filled with long bristlelike teeth resembling the baleen of a whale. These enabled it, standing like a heron in the shallows of the warm Mesozoic seas, to strain from the water its catch of microscopic plants and animals.

In its home in what is now Argentina, *Pterodaustro* became a pioneer in filter feeding millions of years before either whales or such birds as the shearwater and flamingo.

Pterodaustro had a wing span of about 55 inches.

A fair breeze blew, the white foam flew,
The furrow followed free;
We were the first that ever burst
Into that silent sea.

Samuel Taylor Coleridge

Those ancient se
were home and hur
"Wandering Albatro
It was here in a r
spent the daylight h
great unbroken swe
progress unimpede

Arnaldo

Pteranodon

Those ancient seas, where today lie Texas and Kansas, were home and hunting grounds to *Pteranodon*, the great "Wandering Albatross" of the Cretaceous period.

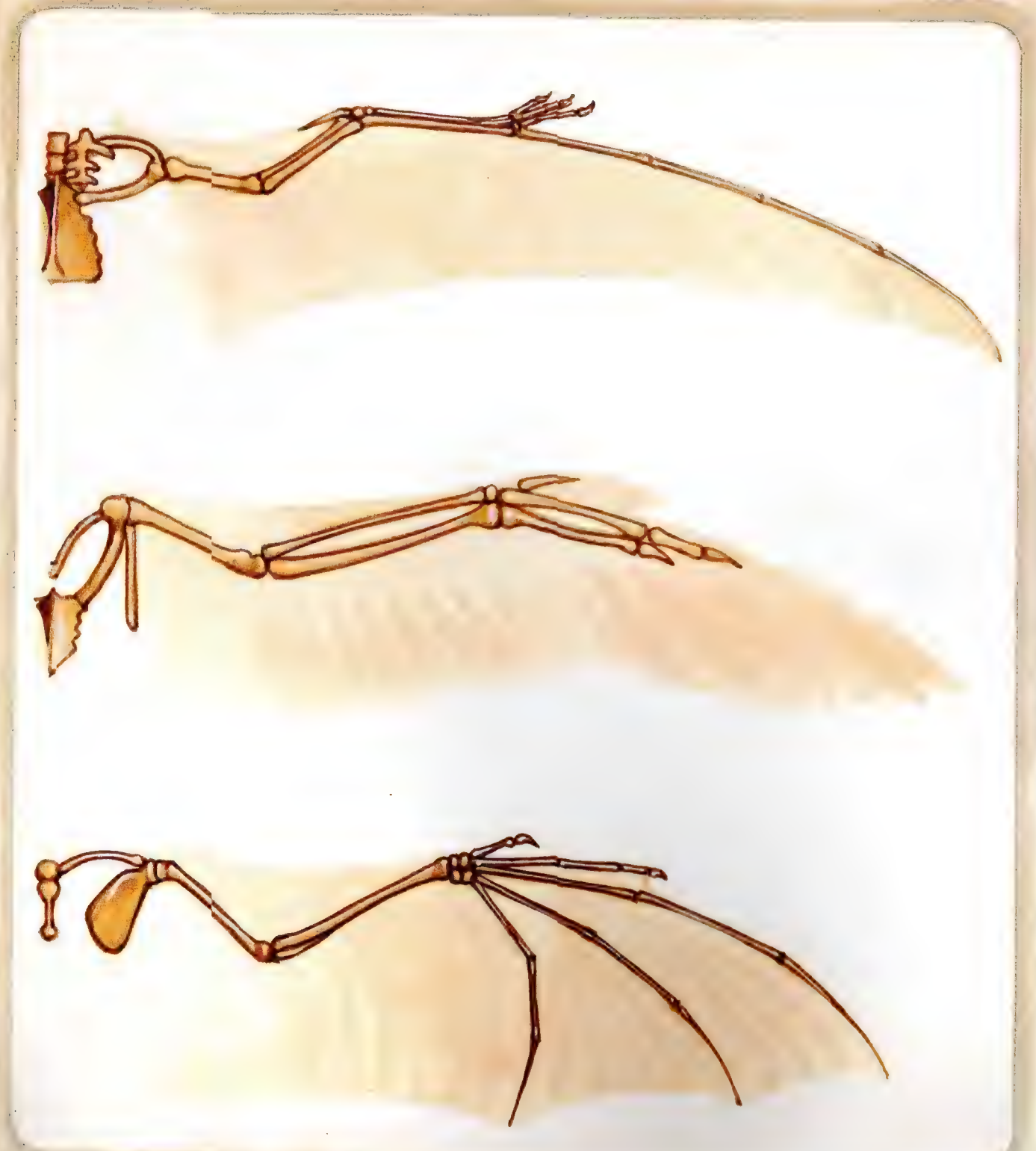
It was here in a mild and gentle climate that *Pteranodon* spent the daylight hours soaring for vast distances the great unbroken swells that ran in from the west, their progress unimpeded for thousands of miles.

He would dip, now and then, his great beak to pluck from the crest of the swells small surface-feeding fish and then on a lowering sun would turn to cruise homeward, his throat pouch heavy with the harvest of the day, to his roost high above the shores of that ancient sea where patiently waited his brood mate and offspring.

Its wings spanned 23 feet, but they supported a body no larger than a goose, with hollow wing bones and backbone. It weighed a mere 35 to 40 pounds, giving a wing-loading close to 2 pounds per square foot, just a bit lower than soaring birds of today.

Pteranodon's great blade-shaped beak was balanced by a huge bony crest extending 2 feet to the rear of its head. No one will ever know for sure whether it served as an aerodynamic balance or if it was just for show.

Take off and soaring speeds would probably have been in the order of 15 to 20 miles-per-hour with a maximum gliding speed of around 25 m.p.h.



The evolutionary changes to the forelimbs of an earthbound animal necessary for a life on the wing follow 3 distinct courses.

Though the upper arm and forearm remain similar and quite recognizable, in each case the main differences occur outboard of the wrist.

This was much longer in the case of the pterosaur, and it retained only 4 digits. The first 3 remained fully developed and functioning but the little finger was the flight finger, much modified and elongated to carry the flight loads of the outer-wing membrane.

Birds solved the flight problem in another way, retaining only 3 digits, the first of which — the alula — carries a small bunch of feathers and acts like the slot in an aircraft wing while the second and third are fused together and carry the stiff pinion feathers and the flight and thrust loads of the outer wing.

The bat's solution was to take an easier way out and just have webbed fingers. Although they are greatly elongated in order to carry the outer half of the wing membrane, all 5 digits still remain.

The principles of flight remain the same, but the structures for achieving it vary greatly among birds, bats and pterosaurs.

Look for instance at the wing of an unfeathered chicken—all bird wings look [illegible] much the same. There's no [illegible] could fly with a scraw[illegible] but cover it with [illegible]

the silky slickness of the aerofoil shape and you have something nearing aerodynamic perfection. The pterosaur did a similar thing with the great sail of skin and bone that formed its wing, but its covering was of hair—long silky hair overlying smoothing underfur, trans-forming an otherwise [illegible] han[illegible]

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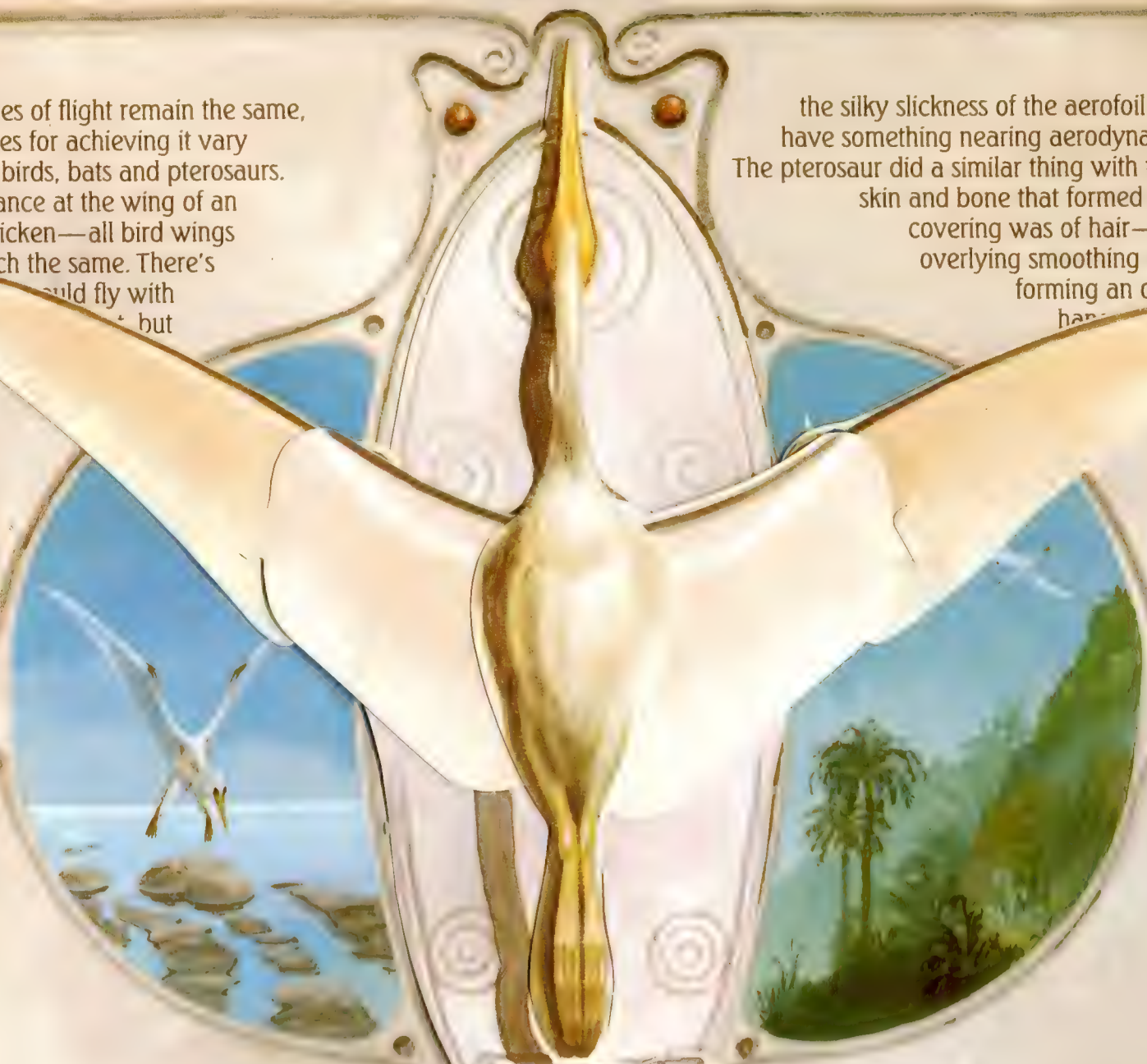


The Flight of the Pterosaur

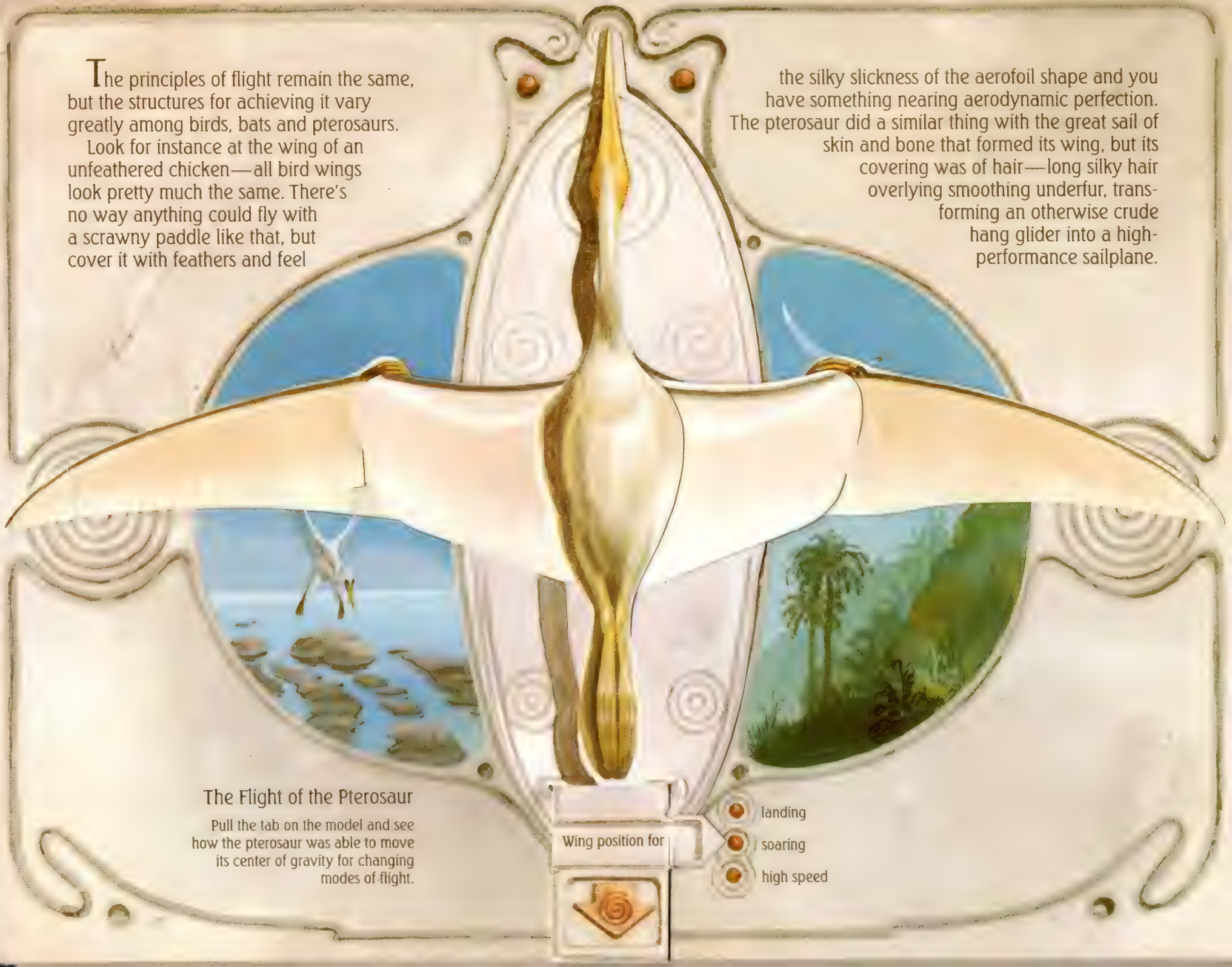
Pull the tab on the model and see how the pterosaur was able to move its center of gravity for changing modes of flight.

Wing position for

- landing
- soaring
- high speed

The principles of flight remain the same, but the structures for achieving it vary greatly among birds, bats and pterosaurs.

Look for instance at the wing of an unfeathered chicken—all bird wings look pretty much the same. There's no way anything could fly with a scrawny paddle like that, but cover it with feathers and feel the silky slickness of the aerofoil shape and you have something nearing aerodynamic perfection. The pterosaur did a similar thing with the great sail of skin and bone that formed its wing, but its covering was of hair—long silky hair overlying smoothing underfur, transforming an otherwise crude hang glider into a high-performance sailplane.



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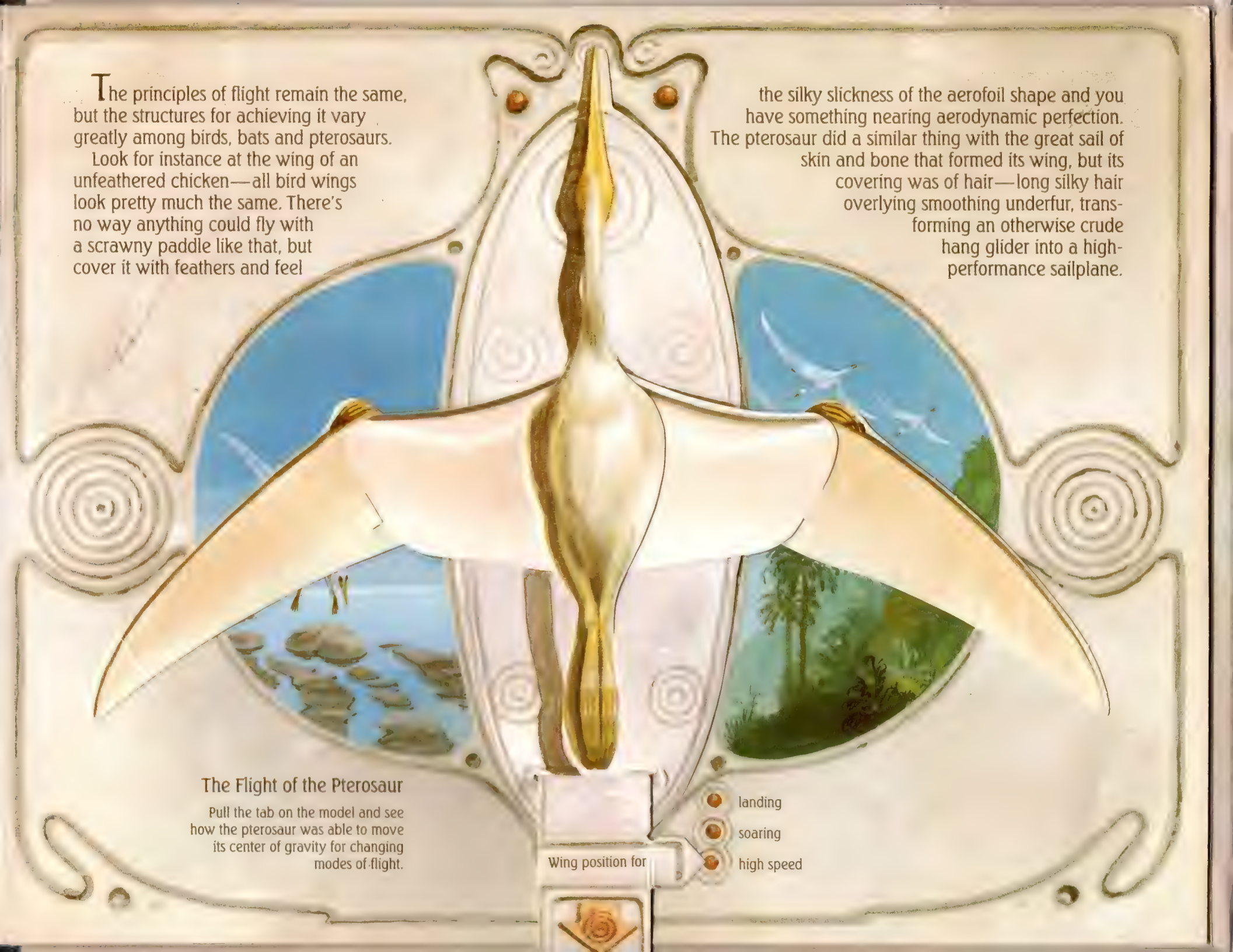

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Quetzalcoatlus northropi

Aloof upon the day's immeasured dome,
He holds unshared the silence of the sky.
George Sterling

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In your mind's eye.
lived, whose great wir
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70 million years before
was named.

See one flying at 10,
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Imagine one sailing
twitchiness as the airsp
high above its head, p
slender toes

In your mind's eye, visualize the ancient Pteranodon as it lived. Picture great wings spanning over 30 feet — nearly the length of a school bus — soaring above the prehistoric landscape. To imagine your creature, follow the folds of these origami instructions.

1 Im Anfang schuf Gott Himmel und Erde.
2 Und die Erde war wüst und leer, und es war finster auf der Tiefe; und der Geist Gottes schwebte auf dem Wasser.
3 Und Gott sprach: Es werde Licht! Und es ward Licht.
4 Und Gott sah das Licht an, daß es gut war. Da schied Gott das Licht von der Finsternis
5 und nannte das Licht Tag und die Finsternis Nacht. Da ward aus Abend und Morgen der erste Tag.
6 Und Gott sprach: Es werde eine Feste zwischen den Wassern und die sei ein Unterscheid zwischen den Wassern.
7 Da machte Gott die Feste und schied das Wasser unter der Feste von dem Wasser über der Feste. Und es geschah also.
8 Und Gott nannte die Feste Himmel. Da ward aus Abend und Morgen der andere Tag.
9 Und Gott sprach: Es sammle sich das Wasser unter dem Himmel an besondere Örter, daß man das Trockene sehe. Und es geschah also.
10 Und Gott nannte das Trockene Land und die Sammlung der Wasser Meer. Und Gott sah an, daß es gut war.

Quetzalcoatlus northropi

Aloof upon the day's immeasured dome,
He holds unshared the silence of the sky.
George Sterling

In your mind's eye, visualize the largest flying creatures that ever lived, whose great wings spanned almost 36 feet, turning majestic circles in the gentle thermals above the plains and wetlands [illegible] 70 million years before the state of Texas, where they were to[illegible] was named

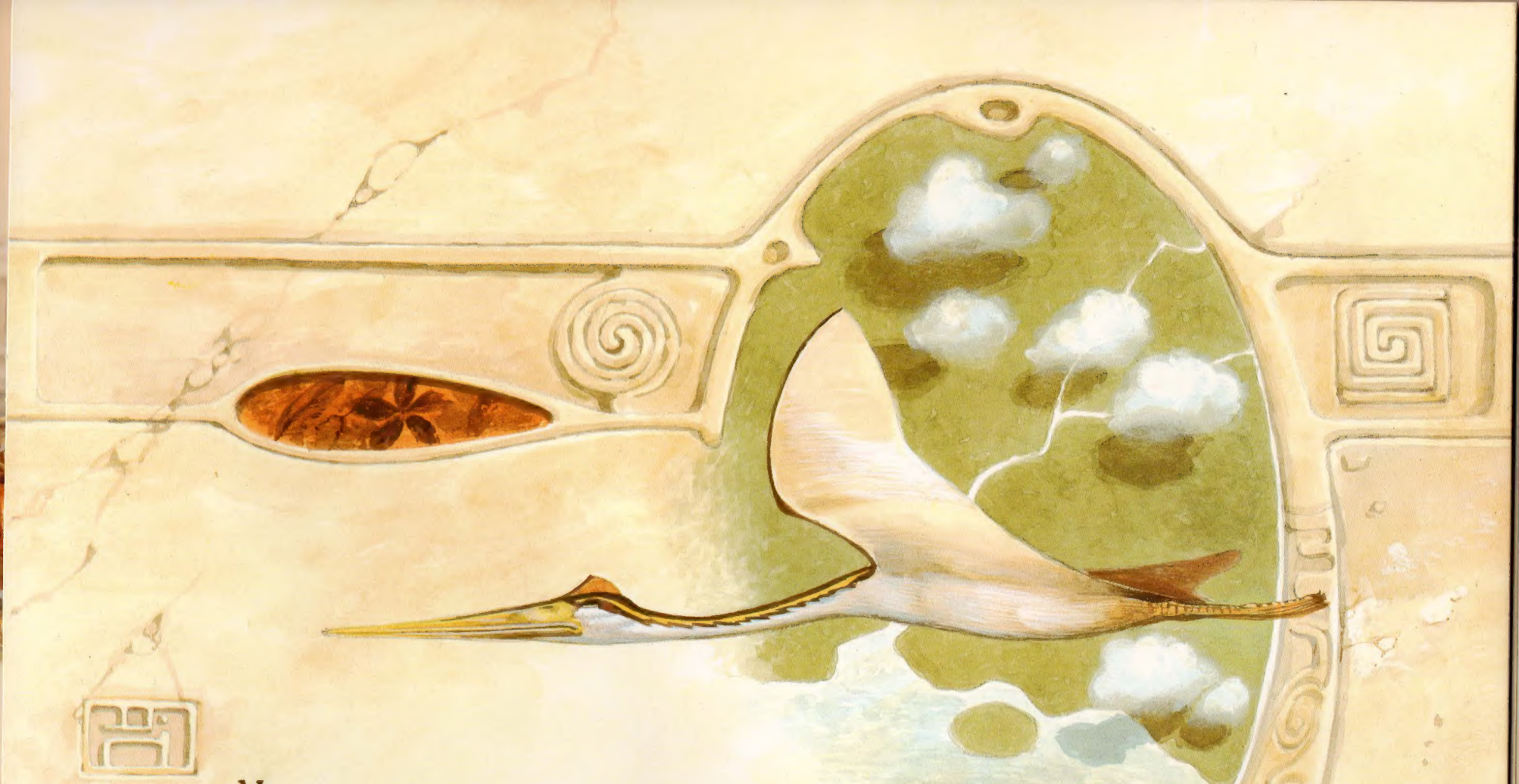
See one flying at 10,000 feet, at the extreme range of [illegible] the height at which you would almost expect a vapor trail. See it [illegible] its majestic circle and head off in an arrow-straight line towa[illegible] upcurrent 20 or 30 miles away where experience and instinct [illegible]

Imagine one sailing in for a landing at day's end, legs trailing, a slight twitchiness as the airspeed falls away, then in the final seconds wings high above its head, parachuting the last couple of feet [illegible] slender toes.

In your mind's eye, visualize the largest flying creatures that ever lived, whose great wings spanned almost 36 feet, turning majestic circles in the gentle thermals above the plains and wetlands more than 70 million years before the state of Texas, where they were found, was named.

See one flying at 10,000 feet, at the extreme range of your eyes, at the height at which you would almost expect a vapor trail. See it check its majestic circle and head off in an arrow-straight line towards the next upcurrent 20 or 30 miles away where experience and instinct steer.

Imagine one sailing in for a landing at day's end, legs trailing, a slight twitchiness as the airspeed falls away, then in the final second, wings high above its head, parachuting the last couple of feet onto its long slender toes.



You may yet again see *Quetzalcoatlus northropi* on the wing, you may yet thrill to the majesty of this great flying reptile whose remains so recently saw again the light of day.

This may only be a ghost, an outline of this great and wonderful beast, stirring a primeval chord for a sight long past; but it *is* there to see.

It is there because Paul MacCready, one of aviation's truly great thinkers, has made it so.

He has built a replica of this great being! In its new incarnation its brain is replaced by a computer and instead of blood coursing through its giant frame, electricity now flows, but it is so lifelike that it would have another *Quetzalcoatlus northropi* guessing.

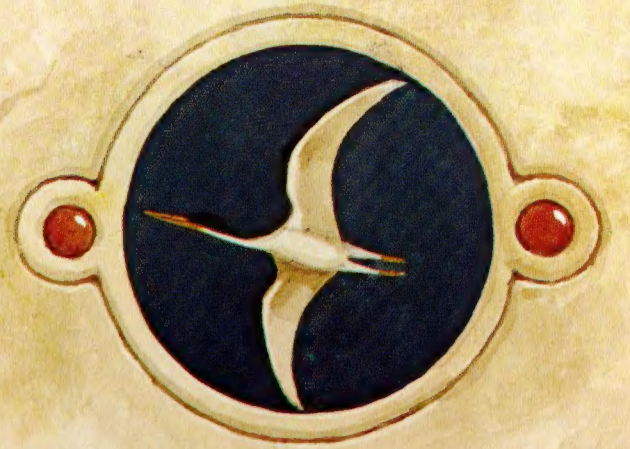
Epilogue

And when on the dying breeze of an evening 60 million years ago, the last of these great creatures glided silently homeward for the very last time, none would record its passing or cheer that final flight.

For there would be no tomorrows for this gentle giant, no more would those great wings be spread to the warmth of an early morning sun or its call echo across the ancient sea.

Yet there remains a memory of its kind, a memory locked away in the genes of the tern and the mallard, the heron and the diver, for they also lived in that ancient time and shared those unremembered skies.

If you love dinosaurs, this is for you: a beautiful pop-up book that brings to life the mysterious flying creatures who ruled the skies when the dinosaurs ruled the earth. The pterosaurs were birdlike, furry beasts. Some were as small as sparrows. And one was the largest animal ever to fly: the *Quetzalcoatlus northropi* was thirty-six feet from wing to wing. This gorgeous and scientifically accurate pop-up book that brings these ancient flying creatures to life was created in cooperation with the Smithsonian Institution's National Air and Space Museum. See the tiny *Pterodactylus elegans* dive over the marsh. Watch the *Pteranodon* soar over the ancient seas. And marvel at the *Quetzalcoatlus* in all its glory. The magic of prehistoric flight is recreated here and can be viewed in the National Air and Space Museum's giant-screen motion picture, *On the Wing.* It lived seventy million years ago. And the *Quetzalcoatlus* flies again, in this book and over our land.



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